Imperial College London

Porter Alliance

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Observations on biofuel potentials and land use

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Structure

- Land use and projections
- Biomass/feedstock productivity
- Role of biofuel technologies

- Concluding remarks

Land use & projections

- 13.4 billion ha of land
- 3 billion ha suitable for crops production
- 1.4 billion ha currently used for crops
- 4.5 billion ha pastures

1960 to present global food production ~x3

Approximately 80% of increase from yield gains, 20% from area expansion

Land use & projections

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Substantial ***variation*** in how increased crop production (1997 – 2030) may occur :-

Region	Land area expansion	Increase in intensity	Yield increase
Global av.	**20%**	**80%**	
All developing	**21%**	**12%**	**67%**
Sub-Saharan Africa	**27%**	**12%**	**61%**
Latin America	**33%**	**21%**	**46%**
SE Asia	**5%**	**14%**	**81%**

After: Smith *et al* (2010) Phil Trans Royal Soc B **365,** 2941-2957

Land use & projections

Smith et al (2010) Competition for Land

Projections for land expansion to 2050 from review of 8 different modelling/ scenario studies

	Range	Av increase
Cropland	+6% to +30%	+15%
Grazing*	-5% to +25%	+10%

*NOTE: a substantial expansion in confined systems for animal husbandry is also projected

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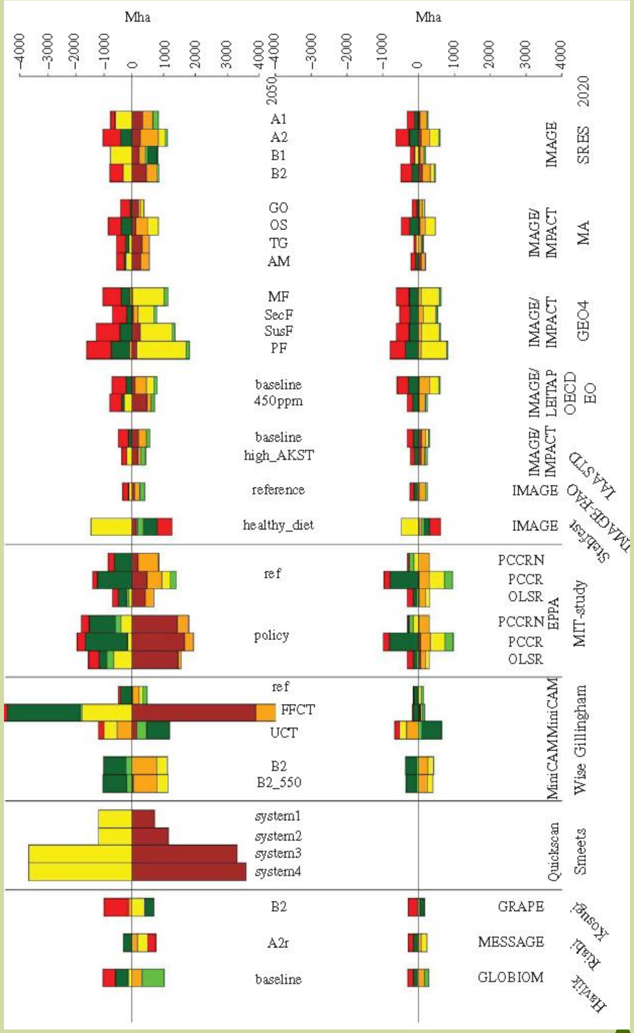
Variation *between land-use change models*

In some (EPPA, MiniCAm, Quickscan) biofuels require between approx. 0.5 to 3 billion ha

In GLOBIOM, competition for land (deforested area as a proxy) reduces under a 2G biofuels scenario vs the Baseline (POLES)



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Causes for some cautious optimism

- Recent study by Wirsenius, Azae & Berndes (2010) shows opportunity for the food system to operate at lower land use e.g. reduced land use from 5.4b Ha in a BAU scenario at 2030 to a possible 4.4 bHa.
See Agr. Syst. (2010), doi:10.1016/j.agsy.2010.07.005

- Some evidence that intensification of agriculture (modelled 1961 to now) giving yield improvements helps to lower GHG emissions from agriculture vs an 'unimproved' BAU case – see Burney et al PNAS (2010)

Land use & projections

BUT ……. there are many reports, publications and models that indicate several constraints:-

- *Water availability/consumption*
- *Ecosystem protection*
- *Agricultural inputs limitations, incl.costs*
- *Others …….*

Land use and Indirect Land Use change (ILUC)

- Review of European Commission’s models from LU perspective
- Comparison of inputs and outputs to understand range of values

Reason for ILUC modelling

Concern of European Commission about impacts of expanded biofuel targets

- **Study 1: *Impacts of the EU biofuel target on agricultural markets and land use: a comparative modelling assessment*. JRC / IPTS (2010)**
- **Study 2: *Global Trade and Environmental Impact Study of the EU Biofuels Mandate*. IFPRI (2010)**
- **Study 3: *The Impact of Land Use change on Greenhouse Gas Emissions From Biofuels and Bioliquids*. DG Energy (2010)**
- **Study 4: *Indirect Land Use Change from increased biofuels demand – Comparison of models and results for marginal biofuels production from different feedstocks*. JRC / IE (2010)**

Key factors determining ILUC emissions

- Physical land use in all world regions
- Impacts of co-products
- Agricultural intensification and area expansion
- Changes in consumption

Key differences in models

- Geographical coverage
- Sectoral coverage
  - Extent to which energy industry is modelled
  - Biofuels
  - Fertilisers
  - Livestock / animal feed
- Crop types modelled
  - Palm oil
  - Soy
- Modelling of co-products
- Carbon pools and fluxes
- Counterfactual scenario definitions
- Future crop yield increases
- Changes in crop rotation frequencies
- Impact of technological advancement
- Mix of feedstocks
- Competitive uses for palm oil

Comparison of models

General model characteristics			Feedstocks & co-products			Endogenous			LU emissions	
Model	Type[1]	Sectors	Crops[2]	2G[3]	Co-products	Expansion	Intensification	Consumption change	Emissions from Fertiliser use	GHG land conversion
AGLINK-COSIMO	PE	Ag	WT, VO, MA, SC, SB	yes	yes	yes	yes	yes	no	no
FAPRI-CARD	PE	Ag	Arable crops, SO, PO	yes - exogenous	yes	yes	yes	yes	yes	yes
IMPACT	PE	Ag	SC, SB, MA, WT, other cereals	no	no	yes	yes	yes	no	no
G-TAP	GE	All	WT, MA, SC	no	yes	yes	Yes	Yes	Yes	yes
LEI-TAP	GE	All	VO, WT, MA, SC, SB	yes	yes	yes	yes	yes	via IMAGE	via IMAGE
CAPRI	PE	Ag	WT, MA, OC, OS, VO, SB	no	yes	no	yes	yes	via DNDC Europe	no
ESIM	PE	Ag	OS, VO, WT, MA, SC	yes	yes	yes	yes	yes	--	--
MIRAGE	GE	All	VO, PO, SC, SB, WT, SO, PO	yes - exogenous	yes[4]	yes	yes	yes	yes	partly

[1] **GE**: Computational general equilibrium models explain the relationship between supply, demand, and prices across all sectors of the economy and assess the impacts of changes within sectors on the rest of the economy over time.
PE: Partial equilibrium models consider only a subset of sectors of the economy (e.g. energy, agriculture, forestry) and model the impacts of changes within these sectors over time.

[2] MA: maize PO: palm oil OC: oil crops OS: oilseeds SB: sugar beet SC: sugarcane SO: soy VO: vegetable oil WT: wheat

[3] 2nd generation biofuels

[4] From feedstock production only

Source: adapted from Netherland Environment Agency, 2010

Inputs: Fuel and Biofuel Demand

- Each study has used different assumptions for
  - Year 2020 transport fuel demand (range 300 – 389.4 Mtoe)
  - Biofuel incorporation levels (2.3 – 5.3% increase from current levels),
  - Role of second generation biofuels (some of the models include 2G biofuels and others do not)

- These differences will have a first order impact upon the results.

Results: GHG Impacts

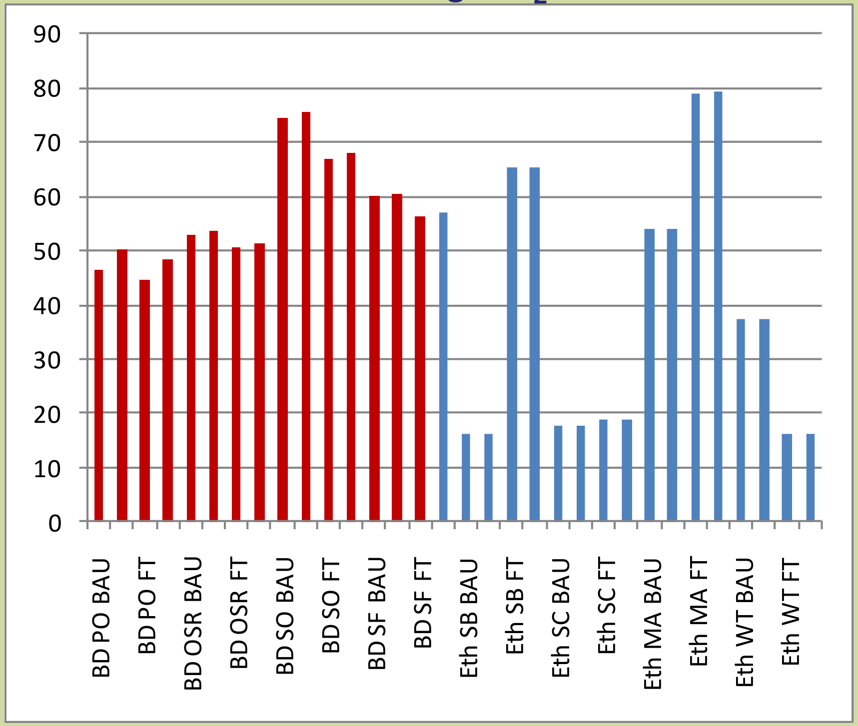
IFPRI/MIRAGE:

- Ethanol: 16.07 – 79.15 g CO_2 / MJ
- Biodiesel: 44.63 – 75.40 g CO_2 / MJ

JRC/IE

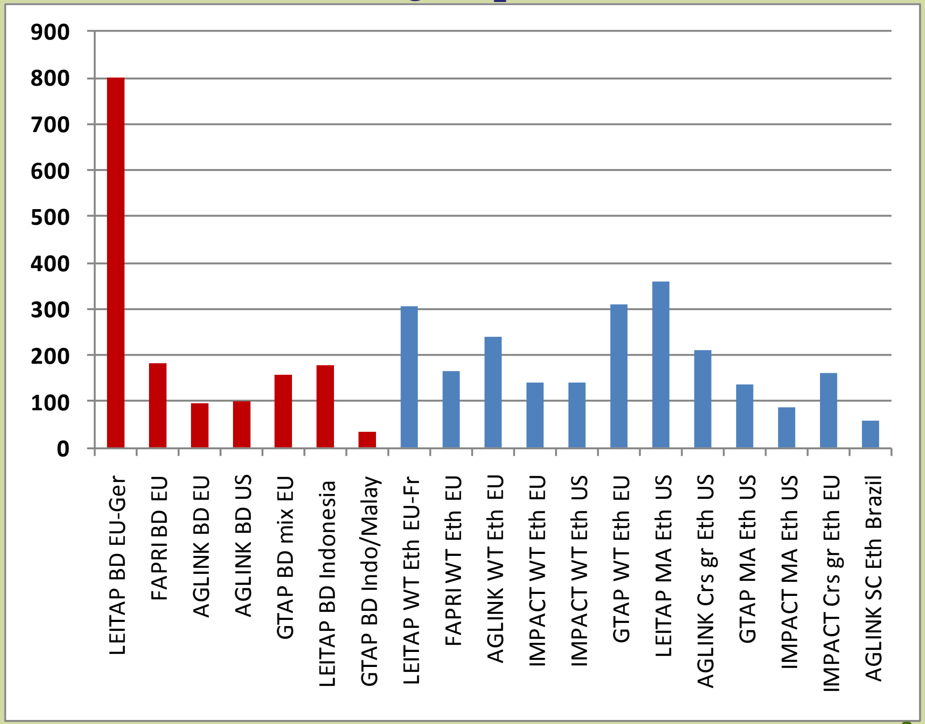
- Ethanol: 56 – 359 g CO_2 / MJ
- Biodiesel: 34 – 801 g CO_2 / MJ

Modelled LUC g CO_2 / MJ



Source: IFPRI (2010)

Modelled LUC g CO_2 / MJ



Source: JRC / IE (2010)

Modelling in context

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Changes in arable land (Mha) (2000-2007)

	Global		EU27	
Year	Total arable land (Mha)	∆ fr. previous year (Mha)	Total arable land (Mha)	∆ fr. previous year (Mha)
2000	1,397.96	--	114.84	--
2001	1,398.03	0.07	112.15	-2.69
2002	1,396.27	-1.76	111.26	-0.89
2003	1,402.60	6.33	110.16	-1.10
2004	1,405.83	3.23	110.02	-0.14
2005	1,412.14	6.31	109.47	-0.55
2006	1,411.72	-0.43	109.28	-0.19
2007	1,411.12	-0.60	108.45	-0.83

Source: FAO Stats (2010)

- 0.07% in global increase in cropland (IFPRI) = 0.0007 x current cropland area (1.4 billion ha) = **1.0 Mha**
- FAO Stat 2000-2007 EU arable area 115 Mha to 108 Mha → decline of 7 Mha
- Average annual variation (2000-2007):
  - Global: **2 Mha**
  - EU27: **-0.9 Mha**

Conclusions

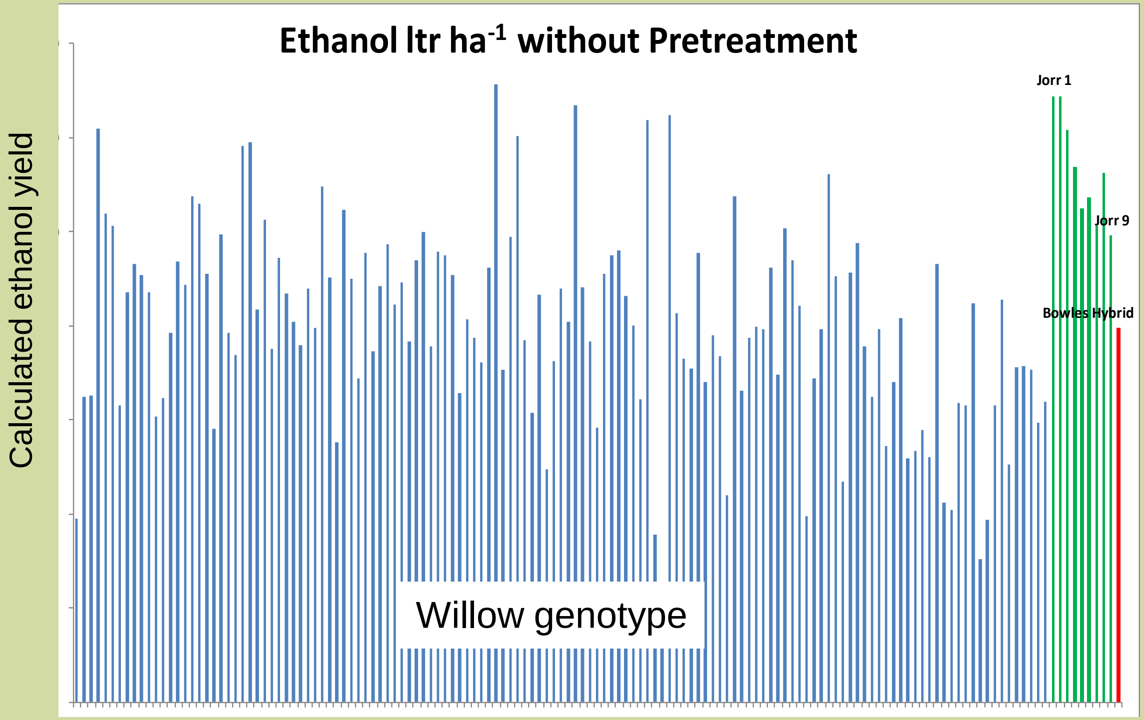
- Models differ in many respects
- Lack of consistency in key input data
- LU implications vary by 1-2 orders of magnitude
- Uncertainties in dynamic environment
  - Unforeseen events / exogenous shocks, e.g.
    - Fires in Russia, Spain
    - Commodity prices,
    - Credit crunch
    - Shifts in geopolitical balance
- Modelled LU change implications lie within the range of annual variation of European cropland

Biomass/Feedstock productivity

Research progress is happening to 'design' 2G feedstocks

e.g. analysis of saccharification yields in willow populations enables discovery of QTL for biofuel at Rothamsted Research/Imperial College

see Brereton et al, 2010 *Bioenerg. Res.* DOI 10.1007/s12155-010-9077-3



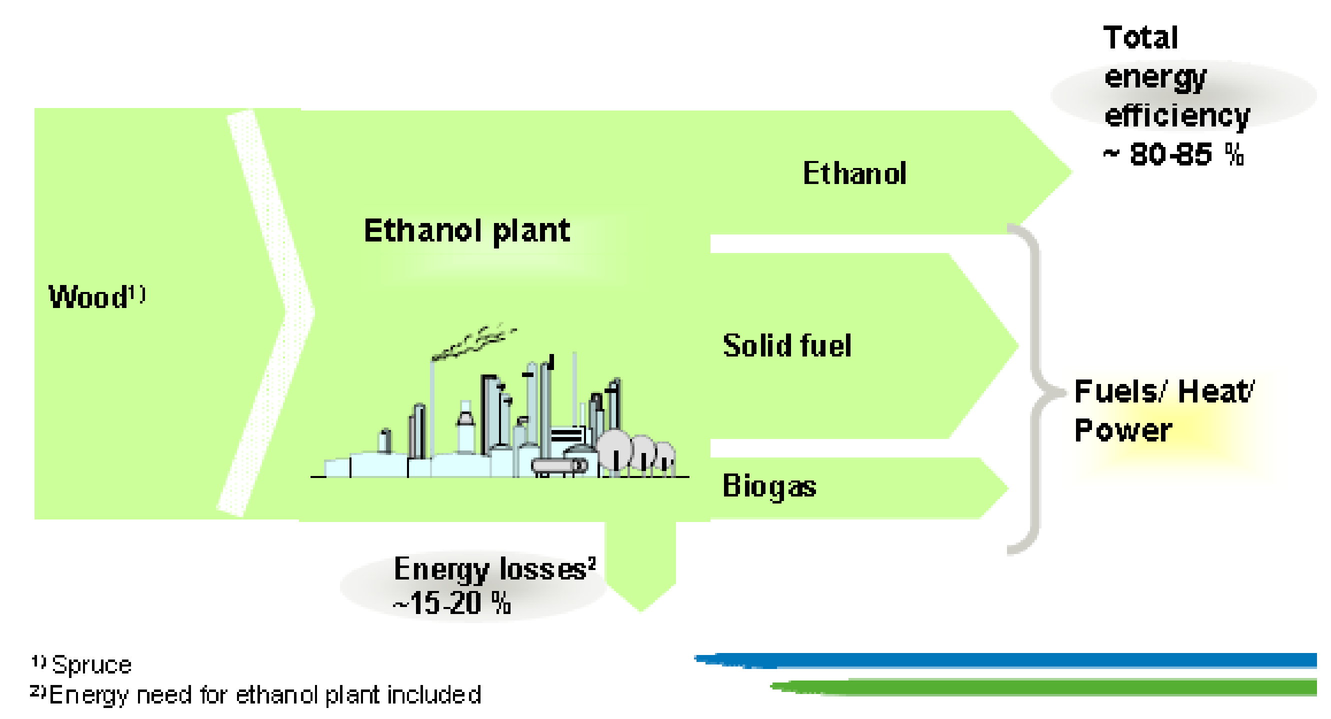
Also see EC FP7 project EnergyPoplar

Biofuel Technologies Role

- *1G biofuel technologies, including co-products - the parameters are well known though development work still continues at scale (e.g. wheat ethanol + DDGS)*
- *No 2G production (at scale) in place - some demonstration*
- *Models for 2G are not well developed e.g. fermentable glucose yields (range 50 to 75% ?, 80 to 95% is aspirational)*
- *It is possible to model the upper bound levels per kg feedstock – feedstock yield is a practical 'unknown' and subject to much potential variation*

Biofuel Technologies Role

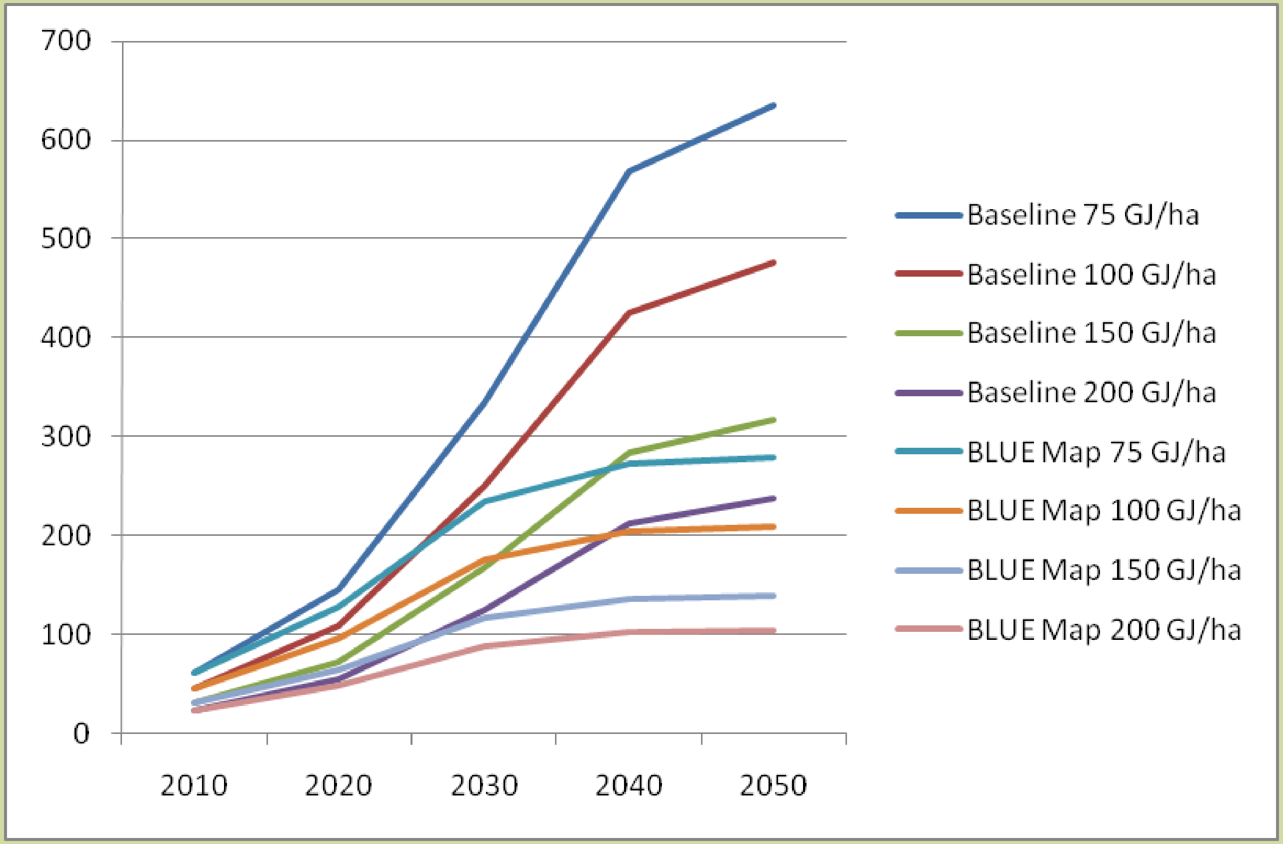
An opinion ….** 2G biofuels are capable of offering advantage (potentially substantial) with application of an **integrated systems approach



From Sune Wännström at SEKAB E-technology

Biofuel Potential Role

A modelled potential regarding Blue Map
(based on our own assumptions for yield (average))



Concluding remarks

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- ***Uncertainty is unavoidable*** in assessing these potentials – caused by ***diversity*** in data and estimates for biomass 'performance' and yield, biofuel technologies, process economics etc
- Modelling results are not facts but are important risk assessments
- There is significant potential to help decarbonise transport
- This needs 'capturing' - ***the best should not be the enemy of the good*** - because doing nothing (or even very little) is in itself a significant problem.